FLAT PANEL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a flat panel display device utilizing fluorescent light generated from an electron beam excitation phosphor material.

A liquid crystal display device is typical of the conventional flat panel display device. The device of this type has been widely used as a notebook type personal computer. The liquid crystal display device is, however, a device which displays an image not by emitting light by itself but by modulating (controlling) an amount of transmitted light. Therefore, it requires a light source on the back surface thereof, resulting in various disadvantages such as an increase in power consumption, a decrease in contrast and a decrease in peak brightness.

FIG. **1** shows an example of the conventional liquid crystal display device with back light.

A diffusion plate **12** and a light guide plate **14** are arranged below a liquid crystal display panel **10**. A fluorescent lamp **16** is provided at one end portion of the light guide plate **14**. Direct light from the fluorescent lamp **16** and reflected light from a reflecting plate **18** are incident on the light guide plate **14**, reflected upward by a reflecting plate **20** provided below the light guide plate **14** and incident on the entire surface of the panel **10** through the diffusion plate **12** provided on the light guide plate **14**. The liquid crystal display panel **10** serving as a light modulator is well known in the art so that the detailed description thereof will be omitted. The liquid crystal display panel **10** has transparent pixel electrodes and controls transmission/non-transmission of light for each pixel.

The fluorescent lamp **12** emits light based on the principal that voltage is applied to a lamp tube having inert gas tightly housed therein, plasma occurs within the tube to generate ultraviolet light and the resultant ultraviolet light is collided against the phosphor material applied onto the inner wall of the tube, thereby exciting the phosphor material to emit fluorescent light.

As described above, the fluorescent lamp as a back light of the conventional liquid crystal display device generates plasma to emit ultraviolet light which excites the phosphor material. Therefore, the conventional device has disadvantages in that light emission efficiency is very low and power consumption is large. In addition, because of the entire emission, light is incident on the entire surface of the panel so that light is incident even on pixels which are not turned on. This leads to lowering of light emission efficiency. Moreover, since light having uniform brightness is incident on the entire surface of the liquid crystal, contrast is lowered. Therefore, even if a certain point in the image is intended to be displayed brighter, the back light has uniform brightness and it is impossible to have a higher peak brightness.

To solve these disadvantages, a field emission display (FED) apparatus has been developed. "Microchips Phosphor Display", IEDM 91, pp 197–200, discloses one example of the FED device. This apparatus utilizes a field emission cold cathode electron source. Though the field emission cold cathode electron source is a kind of a triode as same as the conventional vacuum tube, it is different from the triode in that not a hot cathode but a cold cathode is used in which a high electric field is concentrated on an acute cathode (emitter) and electrons are derived based on the quantum mechanic tunnel effect. The electrons are accelerated by voltage applied between the anode and the cathode and collided against and excited by the phosphor film formed on the anode, thereby emitting light.

The field emission display (FED) apparatus is the same as the conventional CRT in that the phosphor member is excited and light is emitted therefore by the cathode rays. In principle, the FED apparatus can obtain a wide angle of visibility as wide as 180°. However, while the CRT uses a point electron source, the FED uses a plate type matrix electron source comprises an array of very small cold cathodes in microns (1 to 2 μm) for each pixel.

There are two types of the structure of the phosphor member for color display; one is an unswitched anode in which phosphor layers of three colors R, G and B are formed on an uniform ITO layer which serves as an anode and is formed on a glass substrate; the other is a switched anode in which anode electrode layers for the phosphor layers of three colors R, G and B are separately formed and the phosphor layers of R, G and B are sequentially and selectively driven. The latter has an advantage that it is not necessary to respectively form cathodes of pixels of three colors R, G and B and a positional alignment of the anode and the cathode is easy.

The miniaturization of a cold cathode itself has been developed and therefore a very small cold cathode can be provided. However, it has been difficult to manufacture a very small phosphor member (capable of showing high resolution such as photograph) for the following reasons. The constraint to the grain diameter of phosphor particles makes it difficult to separately form the phosphor members of three colors R, B and G for each fine pixel. Since a so-called black matrix wherein phosphor pixels are framed by carbon is formed in order to improve contrast, it is difficult to provide very high resolution.

BRIEF SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a flat panel display device having high precision, high brightness, high contrast and small power consumption.

According to the present invention, there is provided a flat panel display device comprising a light source having a plurality of light source elements, each of the light source elements comprising a field emission type cold cathode, an anode electrode arranged facing the cold cathode, and a phosphor member formed on a surface of the anode electrode facing the cold cathode and emitting light due to electrons emitted from the cold cathode toward the anode electrode; and a light modulator on which the light emitted from the light source is incident and which controls an amount of transmission of each light emitted from the phosphor member.

According to the flat panel display device of the present invention, light generated based on quantum mechanic tunnel effect due to collision of electrons emitted from the cold cathodes against the phosphor member is used as the light source of the image display device. Namely, light is emitted not by generating plasma but due to collision of electrons directly against the phosphor member. This makes it possible to emit light with high efficiency. In addition, since electrons are sequentially emitted from the cold cathodes corresponding to pixels to be displayed, less power is consumed. Further, the use of cold cathodes makes it possible to ensure quite large amount of electron beam current and to form a fine electron beam. As a result, desired point and region of the image can be illuminated bright, thereby enabling higher peak brightness and higher contrast.

Additional objects and advantages of the present invention will be set forth in the description which follows, and